February 1, 2002

Mr. Henry Sepp
Westinghouse Electric Company
Post Office Box 355
Pittsburgh, PA 15230-0355

SUBJECT: ACCEPTANCE FOR REFERENCING OF LICENSING TOPICAL REPORT WCAP-12472-P-A, ADDENDUM 2, "BEACON–CORE MONITORING AND OPERATIONS SUPPORT SYSTEM" (TAC NO. MB1711)

Dear Mr. Sepp:

By letter dated March 29, 2001, Westinghouse submitted WCAP-12472-P-A, Addendum 2, "BEACON–Core Monitoring and Operations Support System," for staff review and approval. The main topical report (TR) was approved by the staff on February 16, 1994. Addendum 2 extends the previously licensed BEACON power distribution monitoring methodology to plants containing platinum self-powered fixed incore detectors and Vanadium self-powered fixed incore detectors.

The NRC staff held a meeting with Westinghouse representatives on June 25, 2001, to discuss the review of the TR. On July 11, 2001, the staff issued a request for additional information. By letter dated August 31, 2001, Westinghouse responded to the staff's questions.

The NRC staff has completed its review of the subject TR. The report is acceptable for referencing in licensing applications to the extent specified and under the limitations delineated in the report and in the associated NRC safety evaluation (SE), which is enclosed. The enclosed SE defines the basis for acceptance of the TR.

Pursuant to 10 CFR 2.790, we have determined that the enclosed SE does not contain proprietary information. However, we will delay placing the SE in the public document room for a period of ten working days from the date of this letter to provide you with the opportunity to comment on the proprietary aspects only. If you believe that any information in the enclosure is proprietary, please identify such information line by line and define the basis pursuant to the criteria of 10 CFR 2.790.

We do not intend to repeat our review of the matters described in the subject report, and found acceptable, when the report appears as a reference in license applications, except to ensure that the material presented applies to the specific plant involved. Our acceptance applies only to matters approved in the report.

In accordance with procedures established in NUREG-0390, the NRC requests that Westinghouse publish an accepted version within 3 months of receipt of this letter. The accepted version shall incorporate (1) this letter and the enclosed SE between the title page and the abstract, (2) all requests for additional information from the staff and all associated responses, and (3) a "-A" (designating "accepted") following the report identification symbol.

Should our criteria or regulations change so that our conclusions as to the acceptability of the report are invalidated, Westinghouse and/or the applicants referencing the TR will be expected to revise and resubmit their respective documentation, or submit justification for the continued applicability of the TR without revision of their respective documentation.

Sincerely,

/RA/

Stuart A. Richards, Director
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 700

Enclosure: Safety Evaluation

cc w/encl:
Mr. Gordon Bischoff, Project Manager
Westinghouse Owners Group
Westinghouse Electric Company
Mail Stop ECE 5-16
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Pittsburgh, PA 15230-0355

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT WCAP-12472-P-A, ADDENDUM 2

"BEACON–CORE MONITORING AND OPERATIONS SUPPORT SYSTEM"

WESTINGHOUSE ELECTRIC COMPANY

PROJECT NO. 700

1.0 BACKGROUND

By letter dated March 29, 2001, the Westinghouse Electric Company (Westinghouse) submitted Topical Report (TR) WCAP-12472-P-A, Addendum 2, "BEACON–Core Monitoring and Operations Support System," for review and approval (Reference 1). The Best Estimate Analyzer for the Core Operations-Nuclear (BEACON) system was developed by Westinghouse to improve the operational support for pressurized-water reactors (PWRs). It is a core monitoring and support package that uses Westinghouse standard instrumentation in conjunction with an analytical methodology for on-line generation of three-dimensional power distributions. The system provides core monitoring, core measurement reduction, core analysis and core predictions. The initial TR, WCAP-12472-P, "BEACON--Core Monitoring and Operations Support System," was approved by the NRC staff on February 16, 1994 (Reference 2). The key aspects of WCAP-12472-P are: (1) the methodology used to obtain the measured power distribution from the Westinghouse standard instrumentation system, that is, movable incore detectors, core exit thermocouples and excore detectors, and (2) the methodology for assessing uncertainties to be applied to the measured power distribution and technical specifications with BEACON as the source of the measured power distribution.

Westinghouse submitted an addendum (designated Addendum 1) to the TR stated above which was submitted to the NRC in May 1996, for staff review and approval (Reference 3). The key aspects of Addendum 1 were the inclusion in BEACON of the capability to predict the rhodium (RH) self-powered neutron detector responses and the methodology to assess uncertainties to be applied to the measured power distributions. The current operating Westinghouse PWR plants are equipped with movable incore detectors to monitor core performance. Addendum 1 extended the BEACON system to other PWR designs such as the Babcock and Wilcox plants and the Combustion Engineering plants. These plants are typically equipped with fixed incore RH self-powered neutron detectors.

The latest submittal, Addendum 2, of WCAP-12472-P, extends the previously licensed BEACON power distribution monitoring methodology to plants containing platinum and vanadium fixed incore self-powered detectors (SPDs).

The purpose of the Addendum 2 submittal is to validate the BEACON monitoring system using platinum and vanadium detectors. The basic principle of power distribution inference of the BEACON system is not changed, i.e., the measured power distribution can be obtained by adjusting the predicted power distribution by the amount of difference between measured and predicted detector responses. The only new aspect of the SPD BEACON methodology is how to predict the detector response from the platinum or vanadium currents. The platinum reaction rate is predicted by the licensed PHOENIX-4 methodology. Westinghouse has chosen to retain the licensed "PHOENIX-P" and "PHOENIX-4" methodologies to predict the detector current. Westinghouse stated that the benefits of this approach are:

a. This is a proven and licensed PHOENIX methodology, which is supported by many critical experiments and plant data.

b. The method is based on basic neutron physics and to the extent possible avoids the use of empirical correlations and data.

c. The platinum or vanadium detectors will replace existing RH detectors and will not require new cabling runs or hardware configurations for data measurements.

2.0 <u>TECHNICAL EVALUATION</u>

Westinghouse submitted Addendum 2 to WCAP-12472 in order to seek implementation of additional features (Reference 1). The features are the use of platinum and vanadium fixed incore detectors instead of the RH detectors, and the use of the licensed PHOENIX-P and the PHOENIX-4 methodologies to predict the detector current.

The primary function of the BEACON core monitoring system is the determination of the three-dimensional core power distribution (Reference 1). In BEACON, this calculation is performed with the NRC-approved Westinghouse SPNOVA nodal method. SPNOVA employs a single effective fast group (EFG) calculation to determine the global flux solution and then uses a local correlation to determine the thermal flux and power distribution. The SPNOVA data libraries and core models are consistent with the NRC-approved Westinghouse PHOENIX/Advanced Nodal Code (ANC) design models and have been extensively benchmarked against operating reactor measurements.

The SPD system has been widely used by the nuclear industry. It is used in place of the moveable incore detectors, thermocouples, incore exit, and excore detectors. However, the primary function of the BEACON methodology, which is to determine the core power distribution, remains the same.

Until now, the BEACON monitoring system utilized the SPNOVA neutronic methodology, employing a one-node-per-assembly (radial) representation to achieve the rapid running times required by hardware platforms available in the late 1980s (Reference 3). The decision to extend the BEACON monitoring capability to utilize incore detectors enables Westinghouse to use the NRC-approved PHOENIX/ANC methodology (Reference 4). This option was available to Westinghouse at the time of the initial BEACON approval, but inadequate computational capabilities at the time necessitated the development of simplified diffusion equation methods in order for the BEACON system to function properly. However, recent workstation advancements, coupled with improvements in numerical solution techniques of the nodal expansion method, have permitted the optional use of the ANC neutronic engine in the BEACON system while maintaining BEACON functionality.

The PHOENIX/ANC is a proven and licensed methodology that is supported by many critical experiments and plant data. The method is based on basic neutron physics and avoids (as much as possible) the use of empirical correlations and data. Another advantage of utilizing the PHOENIX/ANC methodology is that the method can be applied to a wider range of design/operating conditions.

2.1 Platinum Self Powered Detectors

The platinum detectors are very sensitive to gamma flux and mildly sensitive to neutron flux. The depletion rate of platinum is very small and Westinghouse has stated that analysis of data has shown that it could be neglected. Both the gamma and neutron signals are proportional to the assembly power. The gamma response is combined with the neutron response to provide the full detector response to the signal. The responses are obtained from the PHOENIX-4 code. The gamma and neutron responses are generated as a function of assembly enrichment and burnup.

Westinghouse pointed out that the platinum detectors are sensitive to gamma rays emitted by the fuel rods in close proximity to the detectors. Because of this selective response and the power gradients in the assemblies, the actual power distributions in the core environments must be accounted for in determining the detector response. This leads to using fuel pin weighting factors to represent the various fuel pins in the assembly. The power distribution for the various fuel pins are obtained by the ANC methodology.

In this methodology, after each radial node is determined, the 3-D power distribution is normalized to unity. The ratio of the measured to predicted power in each node is defined as the incore calibration constant for that node. This constant is then multiplied by the node fluxes and the node peak powers to generate the adjusted values of these parameters.

2.2 Vanadium Detectors

Vanadium detectors are typically neutron sensitive with similar reaction time as that of an RH detector. The benefit of vanadium over RH is its low depletion, which is a factor of 20 times less than that of RH. The BEACON system determines the detector current I_p as a function of the microscopic cross section. The microscopic cross section is a function of the vanadium number density and is obtained from the PHOENIX code. The instrumentation thimble flux is determined by the pin power reconstruction methodology of the ANC solution code.

BEACON determines the measured power distribution by monitoring the predicted power distribution and multiplying it by the ratio of measured to predicted currents. The current ratio is indicative of the flux distribution, as such. The best estimate of measured power distribution is obtained by adjusting the predicted power distribution by the current ratio.

In this methodology, after each radial node is determined, the 3-D power distribution is normalized to unity. The ratio of the measured to predicted power in each node is defined as the incore calibration constant for that node. This constant is then multiplied by the node fluxes and the node peak powers to generate the adjusted values of these parameters.

2.3 Qualifications of the SPD Model and Measurement Variability

To qualify the BEACON system methodology, plant measurement data were obtained from operating plants and analyzed (References 1 and 4). Data provided in tabular form in this submittal compared measured and predicted detector currents and indicate the plants involved in the qualification process, the RH detector design features, and the history of the SPD flux maps used for the analysis. Westinghouse conducted analyses to verify that the proposed SPD model is capable of predicting the magnitude of the detector current and of determining the detector measurement variability in the operating detector system.

SPD qualification analysis procedures were used to determine the ratio of the core average predicted currents to the core averaged measured currents for all of the SPD maps. Westinghouse pointed out that the averaging process eliminates detector-to-detector variation and provides accurate evaluation of the overall SPD model. Results of the analysis showed that the SPD model is very capable of predicting the magnitude of the detector currents with acceptable accuracy.

2.4 Detector Monitoring Uncertainty

Since the BEACON monitoring system is statistical in nature, the determination of the measured peaking factor is affected by such things as the detector measurement variability, the number and layout of detectors, interpolation techniques, and any differences between predicted and true power distribution. Consequently, Westinghouse analyzed the BEACON system uncertainty using a statistical method in which the detector behavior is simulated on the basis of measurement variability statistics. The details of the simulation methodology are described are WCAP-12472-P-A (Reference 2).

The simulation methodology consists of defining the monitoring uncertainty for a given set of detector configurations as a function of the detector measurement variability and the fraction of inoperable detectors. A bounding uncertainty value is determined from a series of simulation analyses, leading to a bounding 95/95 upper tolerance limit in the assembly power and peak node power. The total uncertainty is obtained by a convolution of components, such as the uncertainty in the power-to-reactor rate ratio and the uncertainty in the hot rod power-to-assembly average evaluation (Reference 1). Review of the analyses conducted by Westinghouse indicates that the SPD methodology can be integrated with the existing BEACON system to provide power distribution monitoring capability for SPD plants. The staff agrees with the analysis and the results obtained by Westinghouse.

The Westinghouse analysis indicated that the platinum and vanadium detectors can be mixed with each other or with RH detectors. A bounding measurement variability will be used by the BEACON system. As an example, the platinum detector measurement variability listed in the submittal is less than the bounding measurement variability used by the BEACON system for the RH detectors. So, during the transition from the RH detectors to the platinum and the vanadium detectors, the BEACON system measurement variability uncertainty will always be bounding. Consequently, the power distribution measurement uncertainties used by the BEACON system with the platinum and the vanadium detectors will bound the power distribution measurement uncertainties as determined by the RH detectors.

2.5 Plant and Cycle-Specific Applications

The BEACON power distribution accuracy is dependent on the accuracy and reliability of both the calculation models and the plant instrumentation system. The BEACON uncertainty analysis includes components that are typically constant and are considered generic, such as the model calibration and the thermocouple cross-flow, as well as plant-cycle-specific components that depend on the condition and performance of the instrumentation systems.

In response to Question 1 (Reference 4), it is indicated that the plant-cycle-specific components will be determined on a plant-specific basis and confirmed each cycle. It is also concluded that in order to ensure that the assumptions made in the BEACON uncertainty analysis remain valid, the generic uncertainty components may require reevaluation when BEACON is applied to plant or core designs that differ sufficiently to have a significant impact on the WCAP-12472-P and the WCAP-12472-P-A, Addendum 2, data bases.

3.0 CONCLUSION

The staff has reviewed the analyses presented in WCAP-12472-P-A, Addendum 2, "BEACON–Core Monitoring and Operations Support System," as well as the responses to the staff's request for additional information, and concludes that, on the basis of the application of the licensed PHOENIX-P/ANC code for the prediction of the SPD currents, the qualification analysis performed against multiple operating plant data, and observed detector behavior consistent with operating plant data, WCAP-12472-P-A, Addendum 2, is acceptable for licensing applications, subject to the pertinent restrictions imposed on WCAP-12472-P-A; WCAP-12472-P-A, Addendum 2; and the associated responses to requests for additional information provided in Reference 5.

4.0 REFERENCES

1. Letter from H.A. Sepp to the U.S. Nuclear Regulatory Commission submitting WCAP-12472-P-A, Addendum 2, March 29, 2001.

2. Beard, C. L., Morita, T., "BEACON–Core Monitoring and Operations Support System," WCAP-12472-P-A, August 1994.

3. Letter from N.J. Liparulo to the U.S. Nuclear Regulatory Commission submitting WCAP-12472-P-A, Addendum 1, May 13, 1996.

4. Nguyen, T.Q. et al., "Qualification of the PHOENIX-P/ANC Nuclear Design System for Pressurized Water Reactor Cores," WCAP-11596-P-A, June 1988.

5. Letter from H.A. Sepp, Acting Manager, to the U.S. Nuclear Regulatory Commission, entitled "Responses to Request for Additional Information on WCAP-12472-P-A Addendum 2, 'BEACON–Core Monitoring and Operations Support System'," August 31, 2001.

Principal Contributors: A. Attard
H. Li

Date: February 1, 2002